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Minnesota Geological Survey Information Systems

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ABSTRACT

Although much information on geological observations, measurements, and inferences is held by the private sector, public geological survey agencies have been charged with maintaining systematic, regional, and jurisdiction-wide information that is meant to clarify the context of site investigations, and to support the progress of research and regional planning. This information includes reports and maps that convey interpretations, and geophysical, geochemical, and geological databases that provide observations and measurements, as well as needed collections of tangible materials such as rock samples and thin sections.

In coordination with the federal role of the U.S. Geological Survey, and international geological survey initiatives, current emphasis at the Minnesota Geological Survey (MGS) is on systematic enhancement of digital information on the statewide scale, while also focusing on county-scale needs. Particular emphasis has been placed on accelerated production of multi-layered, 1:100,000 County Geologic Atlases, complete with associated databases, that are needed for regional management of ground-water resources. In addition, statewide geological mapping compilations are being developed at scales of 1:100,000 and 1:500,000, implementing current digital methods that allow content to be zoomed, queried, and viewed in 3D.

While publication sales, the Website (http://www.geo.umn.edu/mgs/), and ftp capability are being maintained, current intentions are to shift information products to Open Geospatial Consortium-compliant Web Services. This will allow users either to gain access to MGS products though the conventional MGS Web site, or to gain direct access to the data through their preferred GIS platform or Web interface.

INTRODUCTION

The Minnesota Geological Survey (MGS) was established in 1872 by the State of Minnesota as part of the University of Minnesota, to serve the needs of the people of Minnesota for systematic geoscience surveys required to ensure their prosperity, health, and security through stewardship of water, land, and mineral resources. The format of this mapping and monitoring has evolved with the progress of science and technology. Its use has been optimized through accompanying research and outreach, and MGS works closely with university,

government, industry, and community partners to ensure that these ongoing geological, geophysical, and geochemical surveys respond to the evolving needs of societal applications.

Under this mandate, MGS has assembled systematic information and reference materials related to Minnesota geology, not only through its own surveys, but also through cooperation with the U.S. Geological Survey (USGS), and through compilation of information and materials derived from water well drilling, state agency resource and health regulatory activity, university research, mineral exploration, and engineering-related activity.

Reference materials and data resulting from these activities are held at MGS offices in Saint Paul. In addition, MGS contributes to the drill core library and the mineral exploration document archive managed by the Minnesota Department of Natural Resources (DNR) in the town of Hibbing, Minnesota. MGS also contributes to the principal Minnesota paleontological archive, housed on the University of Minnesota Twin Cities campus and managed by the University of Minnesota Department of Geology and Geophysics.

This paper reviews the status of MGS publications, collections, databases, and new geological mapping products, as well as plans for the evolution of these products and their delivery.

PUBLICATIONS

Production of a publication, with specified authorship and series number, has been the conventional way to formally produce information that meets the standards set by the institution, under the direction of the Chief Geologist, and with the authorization of the Director. MGS publications have been released in 25 printed series, such as aeromagnetic maps, annual reports, bulletins, county geologic atlases, guidebooks, information circulars, miscellaneous maps, and reports of investigations.

Unlike the past paradigm in which users were referred to libraries and used book dealers in the case of out-of-print publications, MGS is now making a commitment to ensuring the indefinite availability of all of its publications, by completely scanning and linking to the MGS Website all new and older MGS publications. An exception is the open file series, whose status with respect to indefinite availability remains to be clarified, due to possibly incomplete cataloging and archiving.

Although databases are intended to meet scientific standards in a manner comparable to publications, these databases operate according to protocols distinct from those of publications. For example, the incremental growth of some databases, sometimes on a daily basis, and database maintenance are not usual requirements of standard publications. In addition, MGS from time to time produces contract deliverables, and if no series number is assigned to those products, no commitment is made to the long-term availability of the item.

Catalog and collections

The MGS publications database will progressively be enhanced as indexing practices evolve. The hard-copy collections of every publication with a series number released by MGS since inception of the agency in 1872, other than open files, have been updated, at the Minnesota Geological Survey library, at the University of Minnesota library, and in University of Minnesota archives. MGS will ensure the ongoing availability of this database to, for example, the National Geologic Map Database.

Searchable page scans

Since 1872, the MGS has published over 40,000 pages of reports. With support from University of Minnesota Libraries, Digital Collections Unit, these have now been scanned by a contractor (Figure 1). Files in PDF format with searchable optical character recognition (OCR) content have been created, and are now linked from the MGS Website . We plan for the scans to also become digital books that can be quickly searched and viewed on the Web on a single-page basis, rather than time-consuming whole-file download, as soon as format evolution stabilizes. Bound foldouts in the original publications will be part of the PDF files and digital books whereas folded inserts will be available as separate images, in the scanned map collection.

Figure 1. The 40,000 pages of reports MGS has published, which fit in six boxes, were scanned by a contractor in two batches.

Web accessible map images

MGS has published over 600 maps in its history. These were scanned as one batch with support from University of Minnesota Libraries, Digital Collections Unit. Raster files are now linked from the Web site, and PDF files are available for download (Figure 2). There will be ongoing effort to optimize searchable OCR content in these files. Folded inserts from reports are included among these maps.

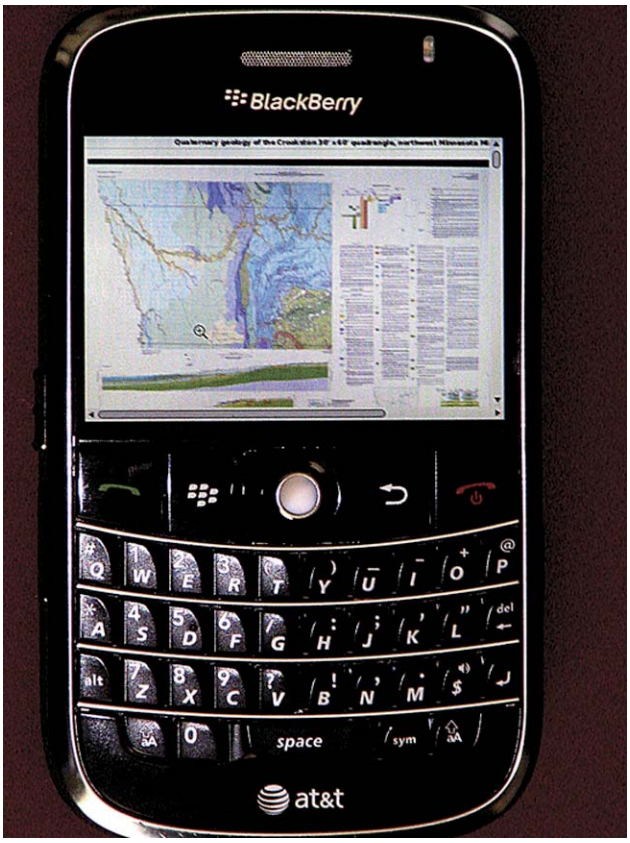

Figure 2. The 600 maps MGS has published were scanned in one batch and are web accessible as rasters.

COLLECTIONS

MGS collections include field notebooks, hand samples, thin sections, sediment samples, geochemical samples, and cuttings (Figure 3). Each collection is accompanied by a database of metadata, such as sample identification, field location, and storage location. Concurrently, DNR administers the drill core library (Figure 4) and mineral exploration file archive, and the University holds the paleontological archive; both collections are well cataloged and stored. MGS presently is working with support from the USGS Data Preservation program to improve cataloging of its collections. Ideally, every item would be cataloged and georeferenced, such that it is mappable and findable. The hand samples are, however, only cataloged at the collection rather than item level. In the case of both hand samples and thin sections, much of the location

information remains at the project rather than the item level. Long-term plans call for gradual improvement of item-level cataloging and georeferencing of the collections.

Figure 3. MGS hand samples have been cataloged at the project, but not yet at the item, level.

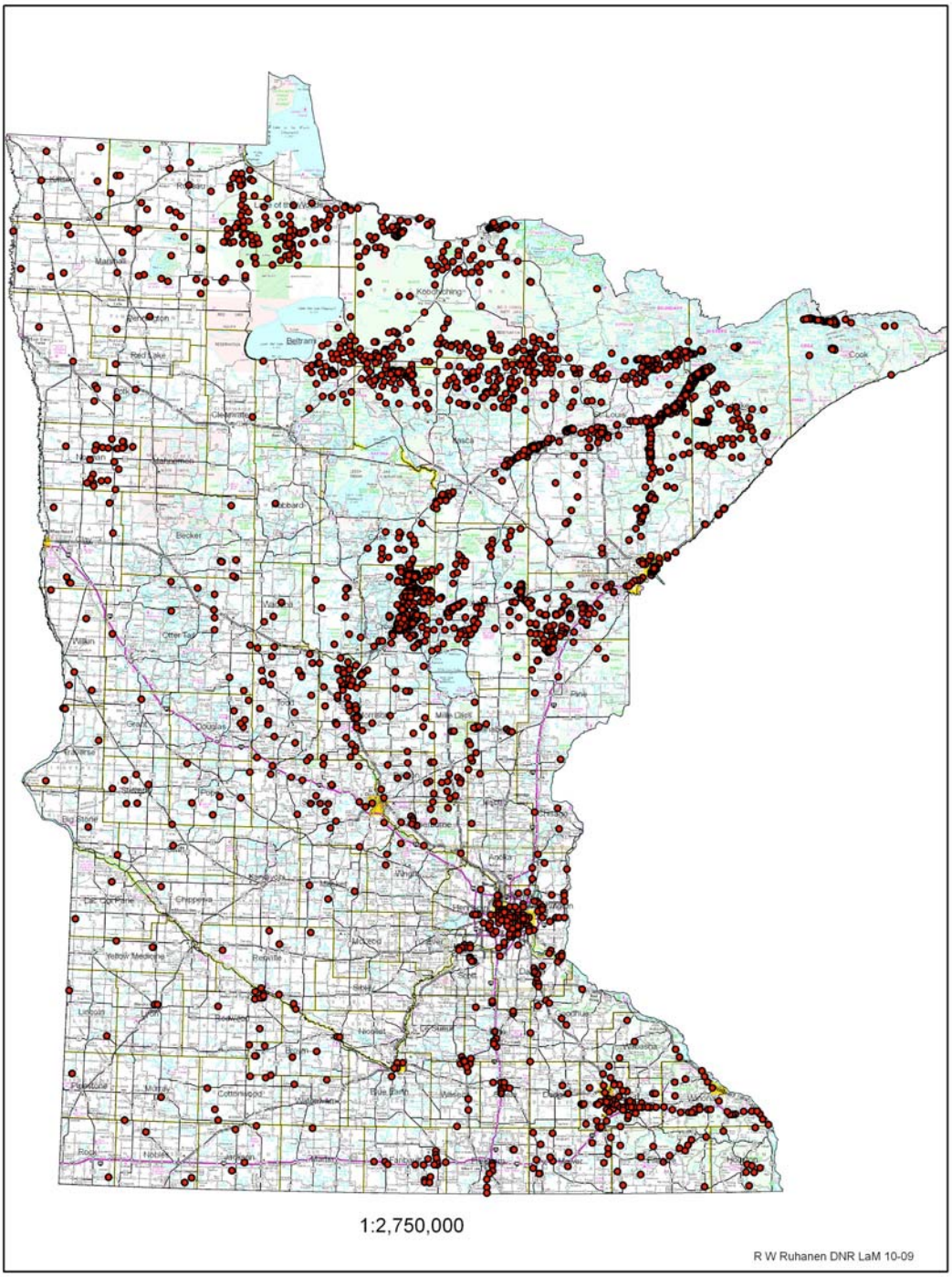

Figure 4. The DNR drill core library holds core from sites across the state; figure derived from the library catalog.

DATABASES

MGS databases include field observations, karst database, sediment textural and lithological data, geochemical database, aeromagnetic database, gravity database, rock properties

database, borehole geophysical logs, the County Well Index water well database (Figures 5 to 8) that MGS co-manages with the Minnesota Department of Health (MDH), and geotechnical data. Materials and data are well stored, although document collections associated with partially digitized content are vulnerable to damage from various natural disasters. Priority for improvements has been placed on the most pressing database content enhancements, more consistent and interoperable database structures, and improved Web accessibility.

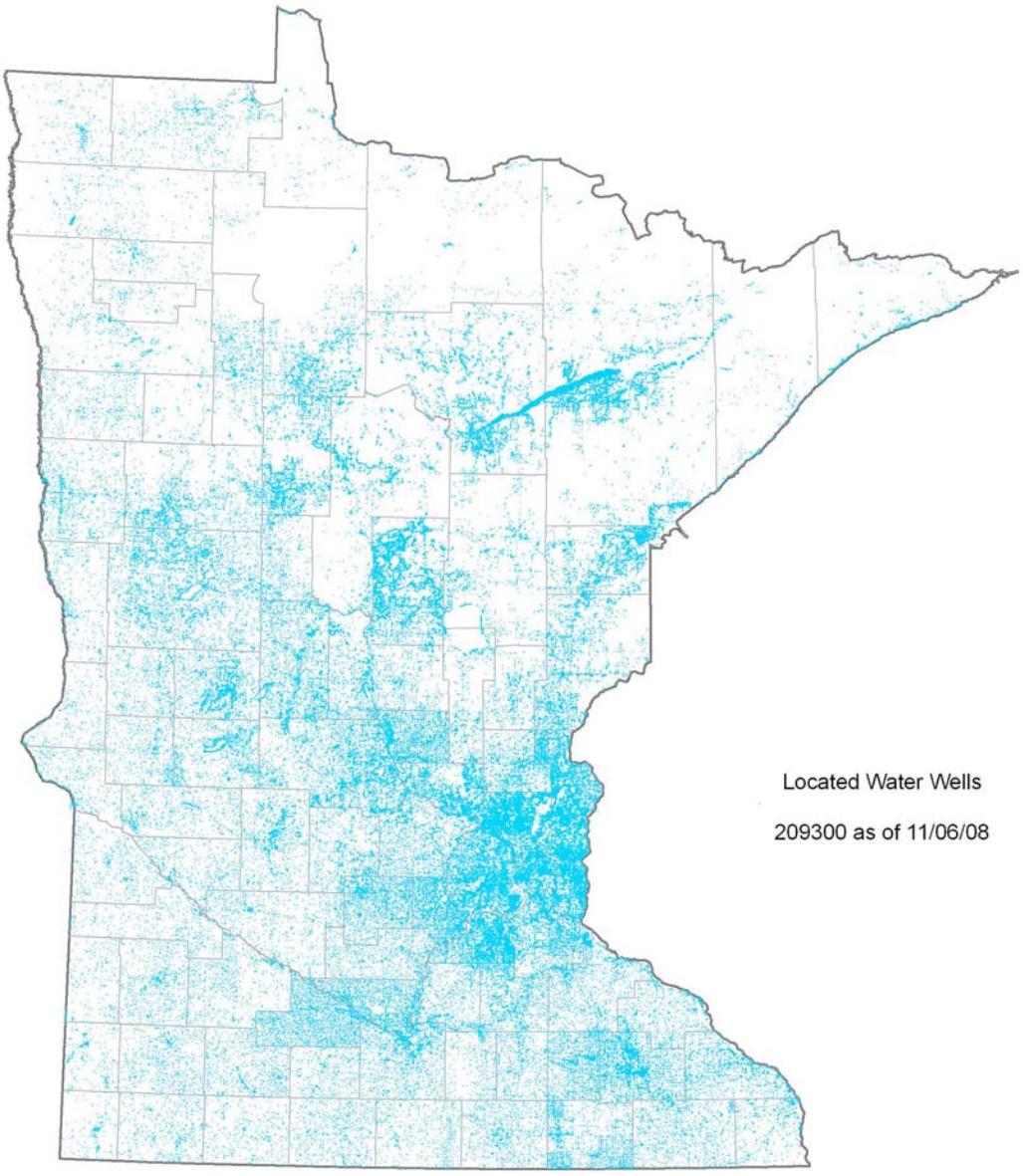

Figure 5. Distribution of located sites in the Minnesota drillhole database; figure derived from the database.

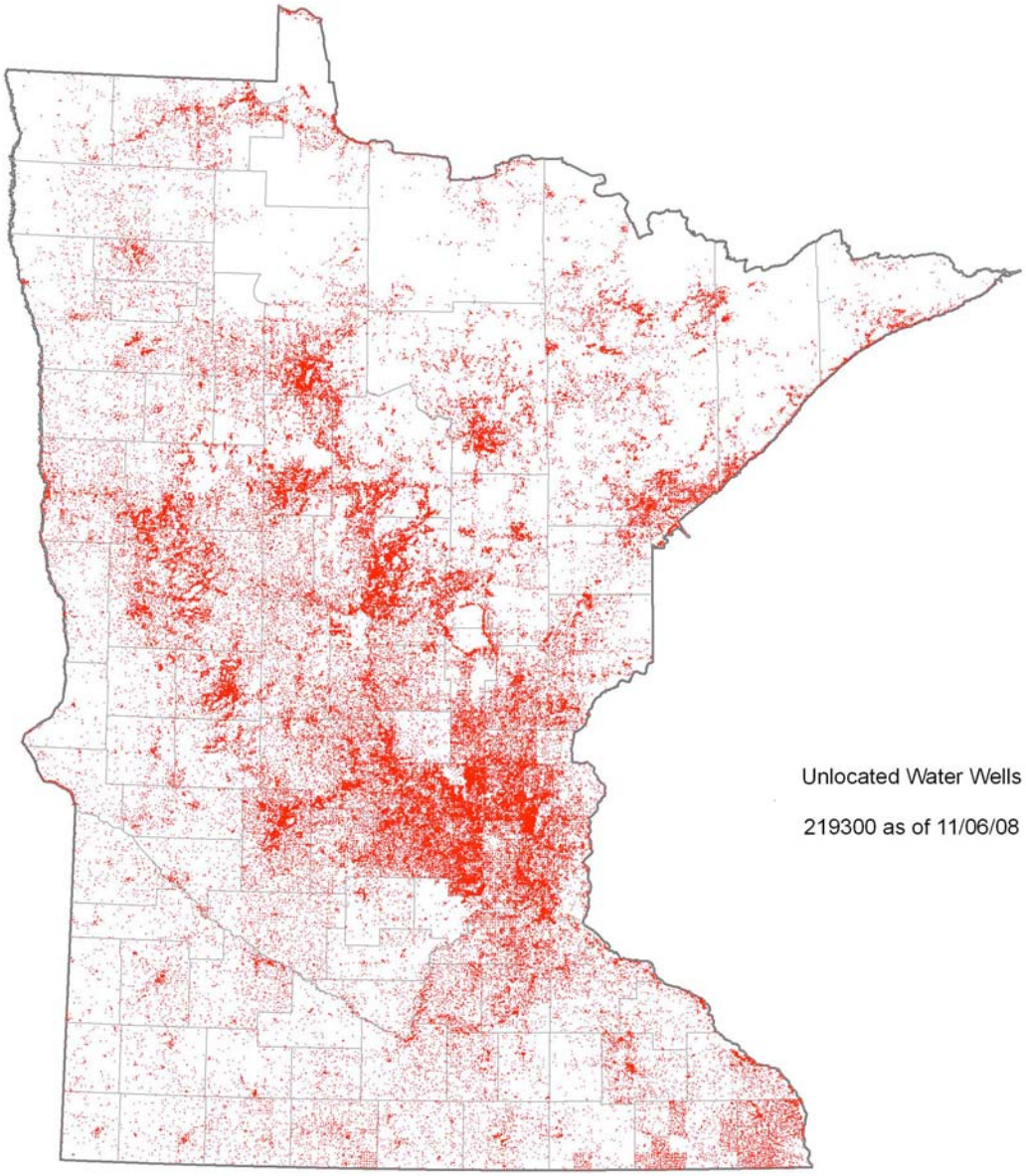

Figure 6. Distribution of sites in the Minnesota drillhole database located to legal survey polygon only; figure derived from the database.

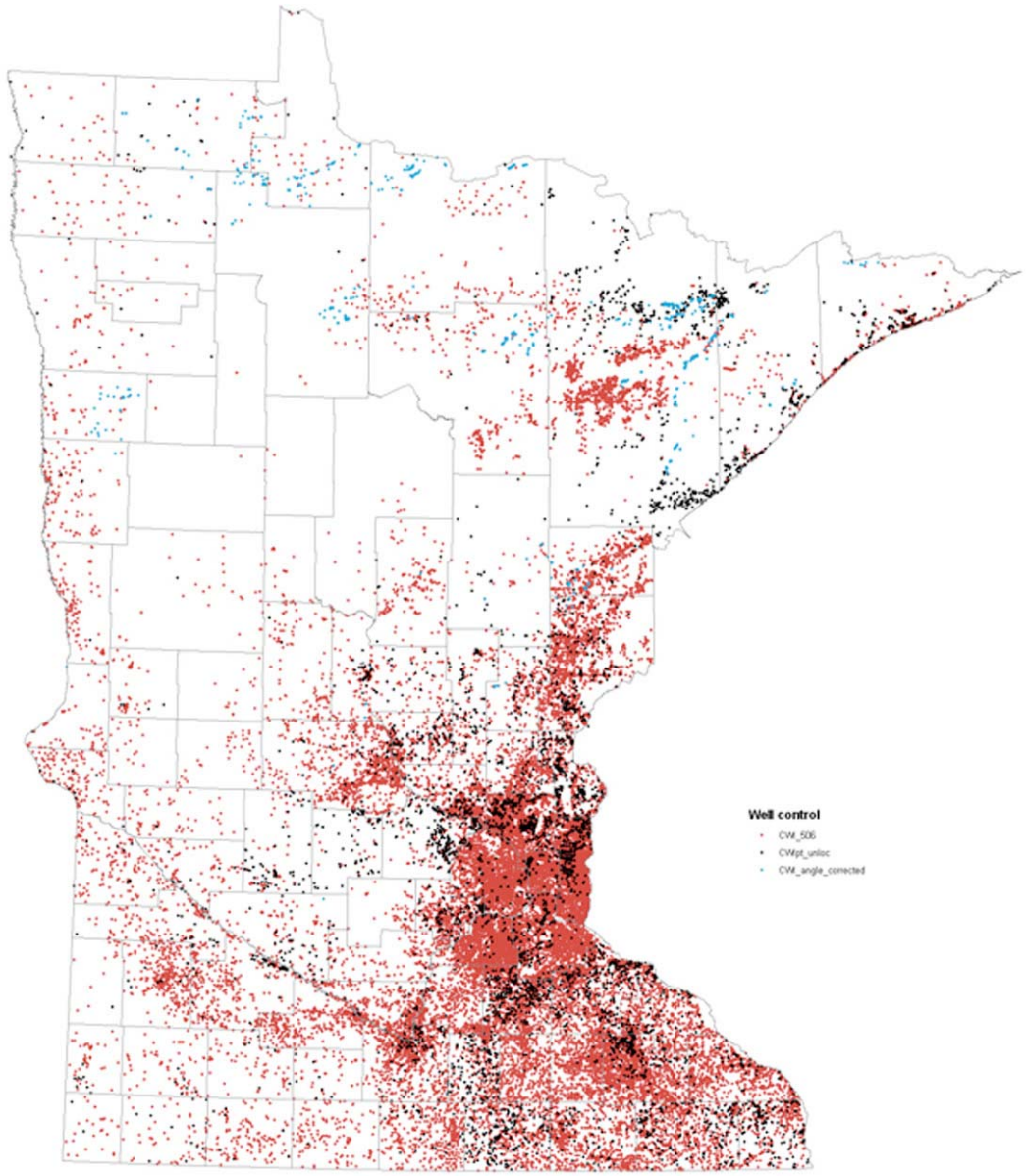

Figure 7. Distribution of drillholes that intersect bedrock, including located, unlocated, and inclined holes; figure derived from the database.

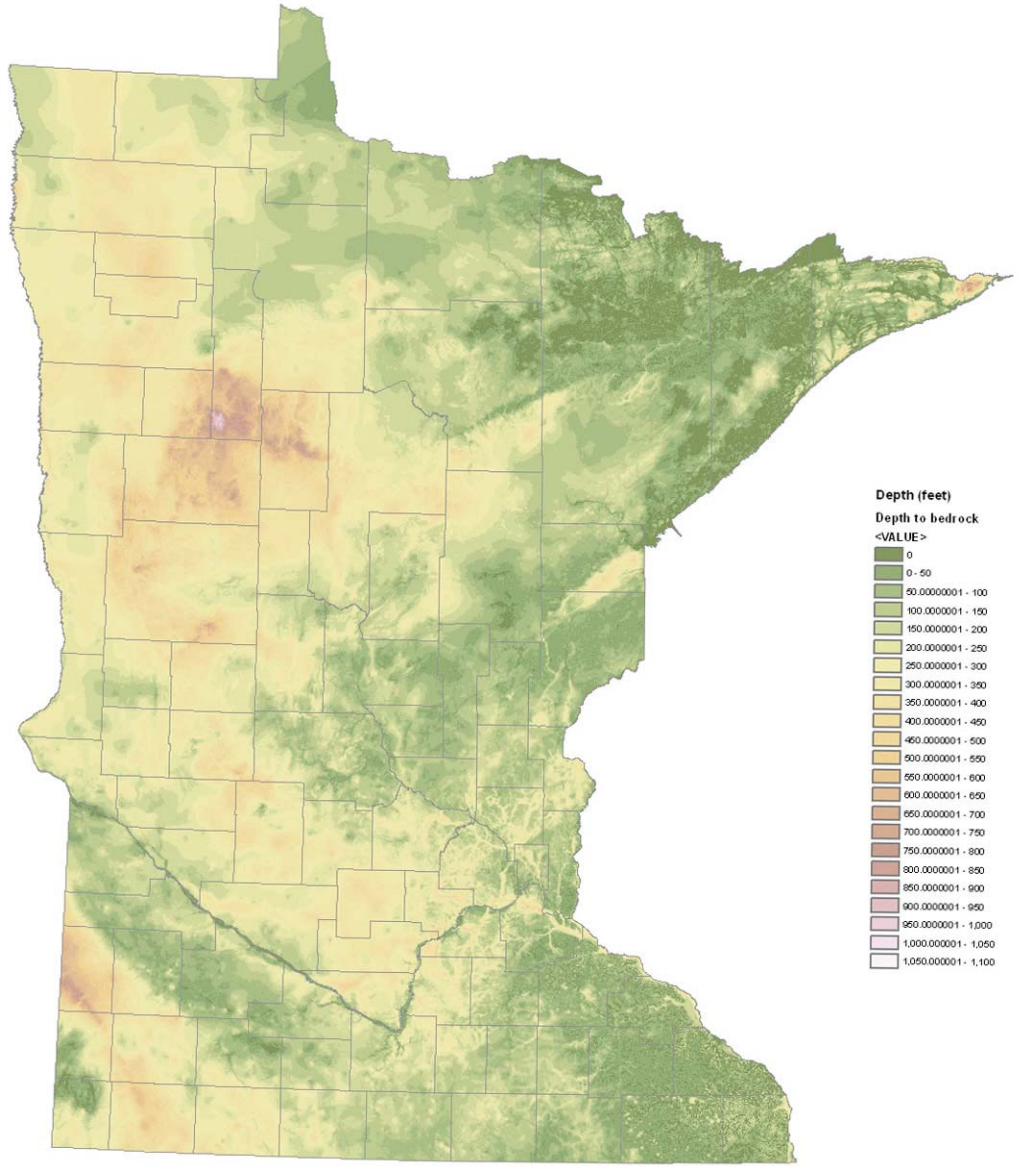

Figure 8. Map of bedrock topography produced from bedrock intersections in the Minnesota drillhole database; from MGS working files.

Enhancements to geophysical databases

In 2007, the Minnesota aeromagnetic database was reprocessed to recover line data missing from the original digital archive, to mitigate line-leveling errors that locally caused striping artifacts, and to use the revised data to produce a higher-resolution aeromagnetic grid for the entire state, resulting in a much-enhanced ability to resolve features (Figure 9). In the months ahead, the 58,000-site gravity database will similarly be improved by enhancing station location precision (Figure 10). In addition, the rock property database that provides density, magnetic susceptibility, and other data that are used to link geophysical properties to geological mapping will be updated with elevations and downhole information where available.

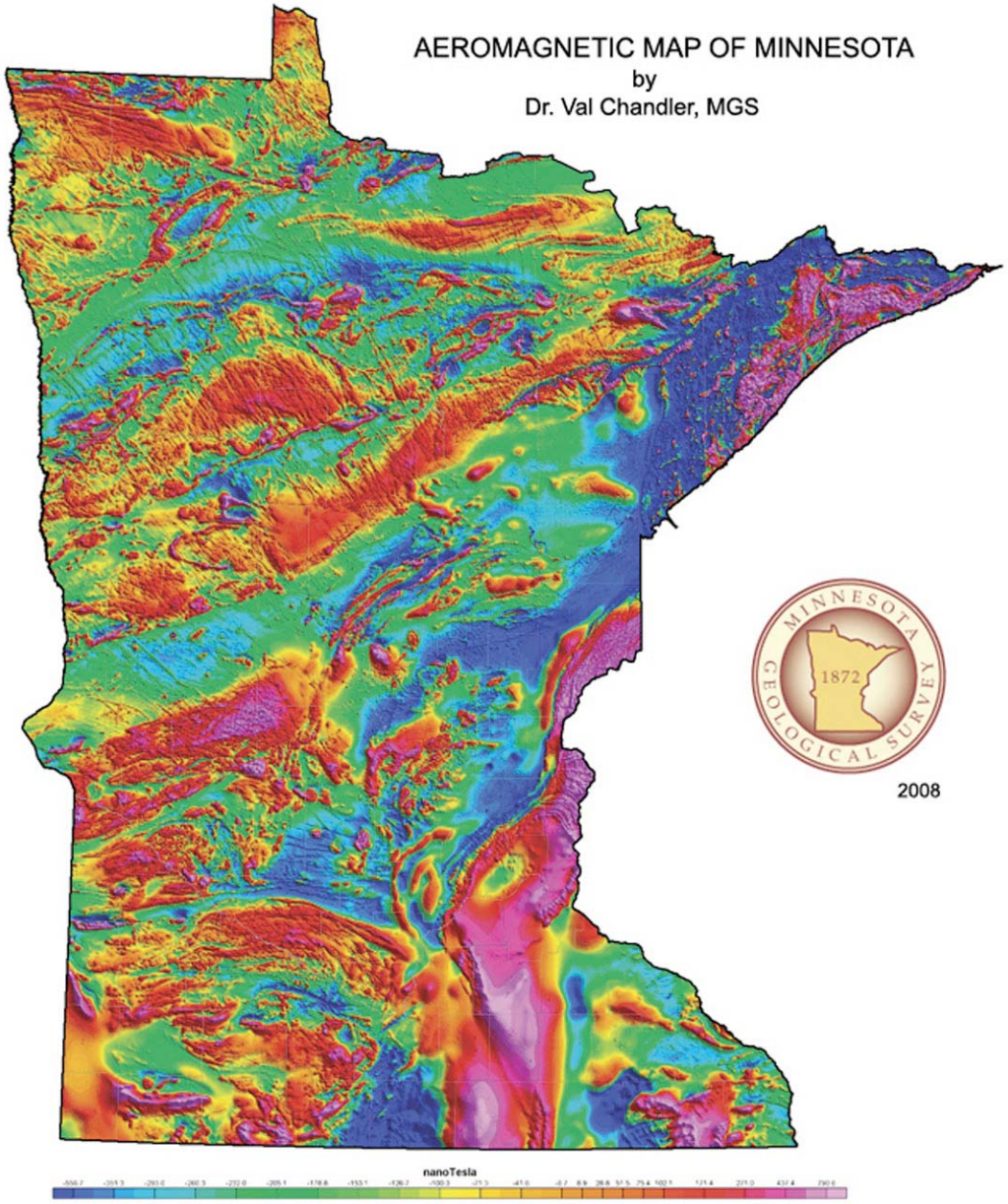

Figure 9. Greatly enhanced feature resolution has been obtained by fully re-processing the magnetic database (http://www.geo.umn.edu/mgs/magnetics.htm).

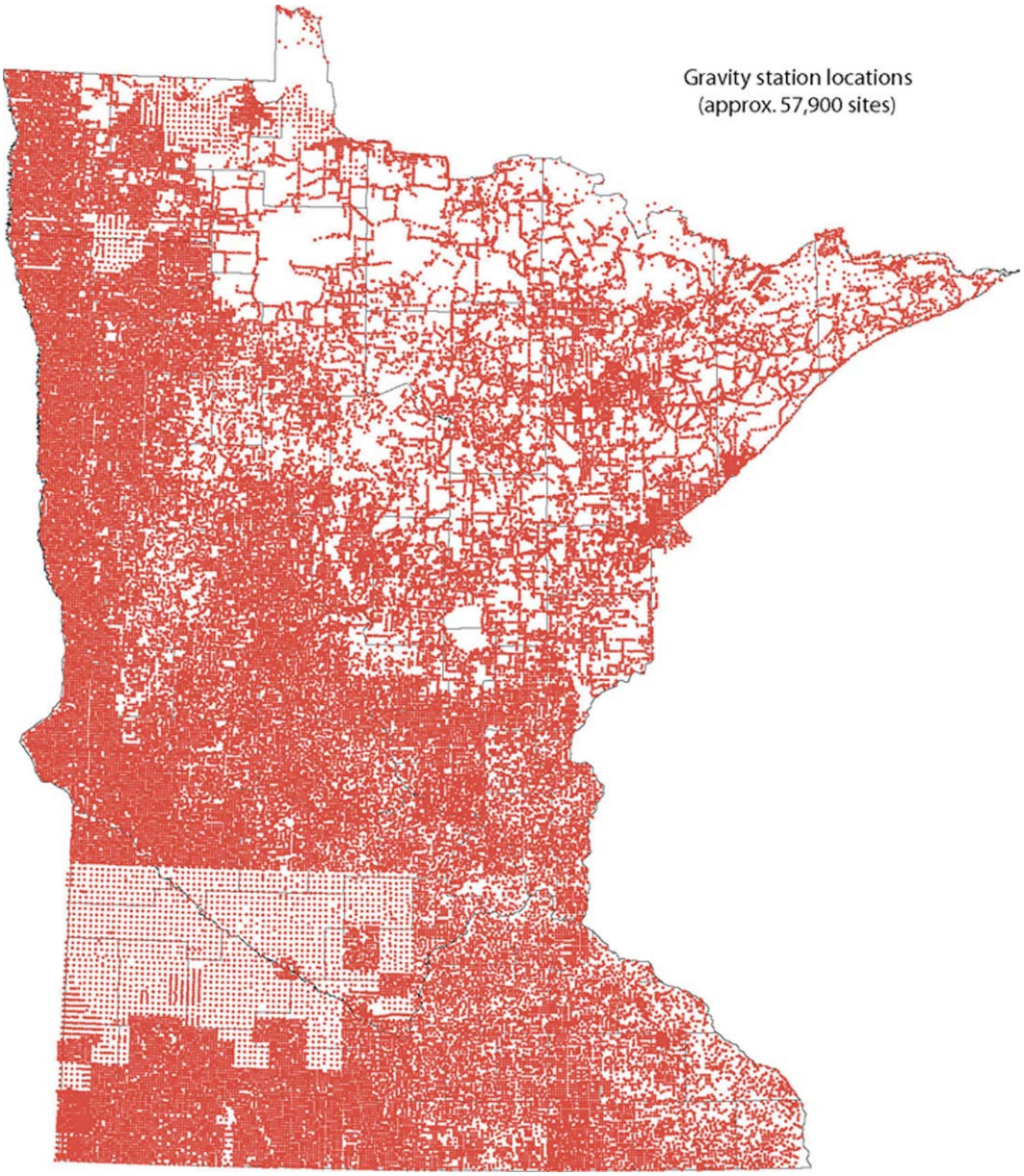

Figure 10. The gravity database will be enhanced by improving site location precision (http://www.geo.umn.edu/mgs/gravity.htm).

Geochemical database

The need for documented statewide geochemical information is escalating, as exploration geochemical surveys need reference data to provide regional context, because project permitting requires documentation of current conditions, and cleanup efforts require information about existing background levels of contaminants. MGS therefore worked with the USGS and the Minnesota Pollution Control Agency between 2007 and 2009 to assemble and map statewide geochemical data for soil, soil parent material, and ground water in selected aquifers. Resulting documentation, maps, a poster, and databases are now online (Figure 11, http://www.geo.umn.edu/mgs/geochem_rpt/geochem_rpt.htm).

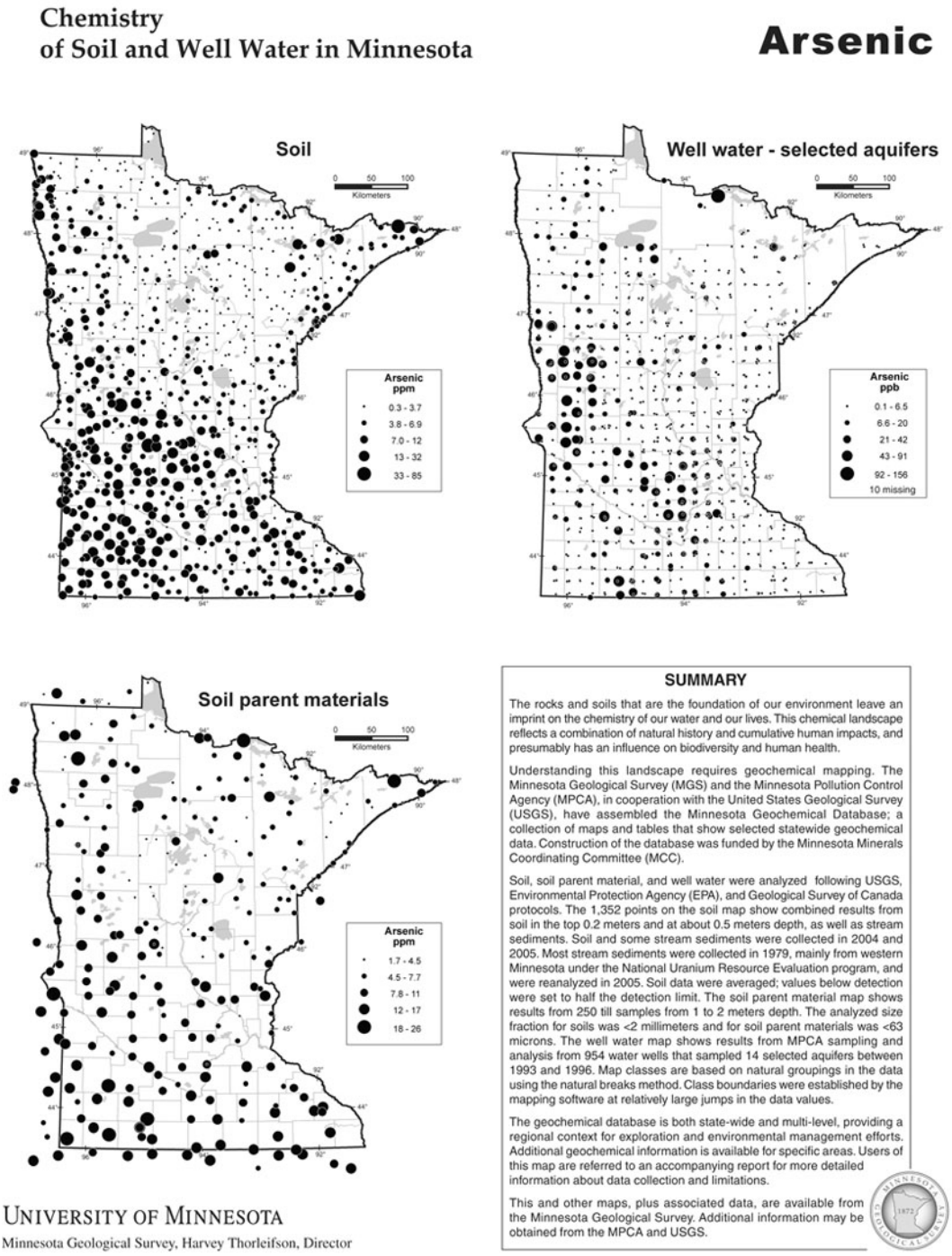

Figure 11. A geochemical atlas has been produced to depict soil, till, and ground-water geochemical data (http://www.geo.umn.edu/mgs/geochem_rpt/geochem_rpt.htm).

Compilation of hydrogeological properties

Regional hydrogeological characterization of ground-water systems is an ongoing high priority activity for MGS. Increased effort therefore is being directed at quantifying hydrogeological characteristics, initially focusing on the most heavily used carbonate and sandstone aquifers in southeastern Minnesota (Runkel and others, 2003). Based on compilation and interpretation of a large amount of hydrostratigraphic and hydraulic data, a hydrogeological framework is being developed that is influencing ground-water management strategies, and improving the ability to predict aquifer productivity and contaminant transport, by providing improved definition and characterization of groundwater systems. Plans call for this activity to eventually be broadened to the statewide scale, and for ground-water systems hosted by Quaternary strata to be better characterized (Figure 12).

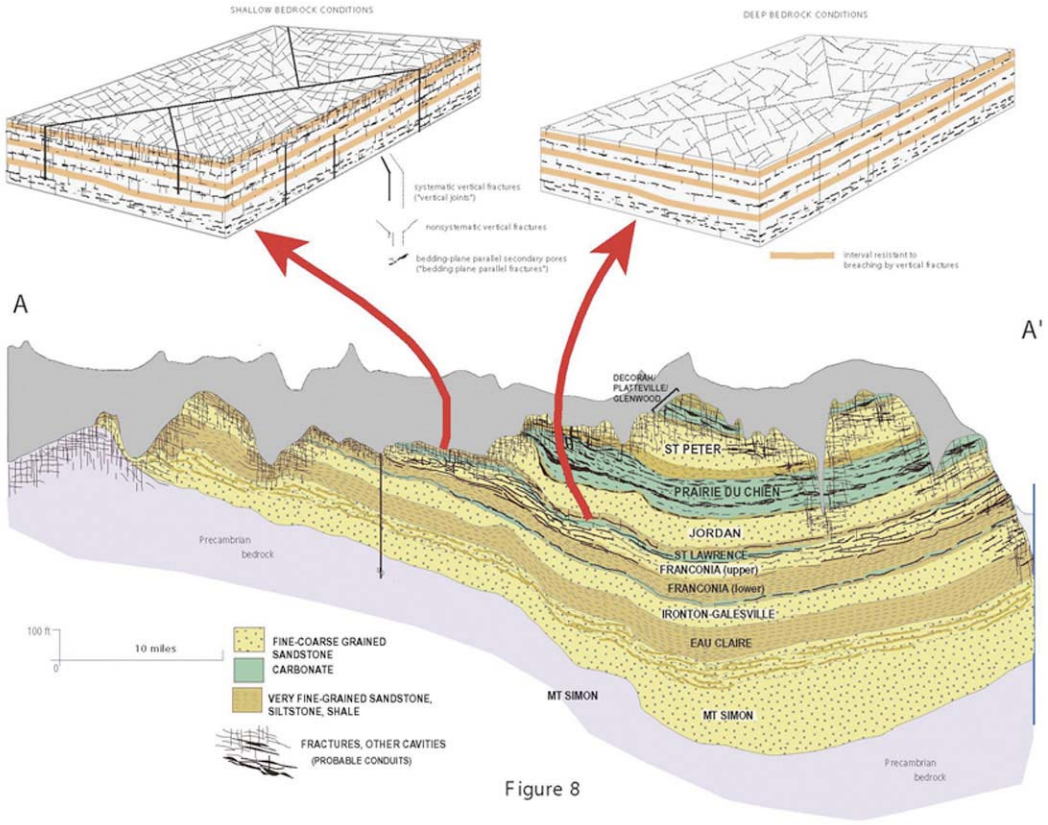

Figure 12. Graphic depiction of hydrogeological properties; increased compilation of hydrogeological measurements is being considered (from Runkel and others, 2003).

NEW GEOLOGICAL MAPPING PRODUCTS

Geological maps were devised nearly two centuries ago, and since that time, they have had a consistent format designed to accommodate the constraints of the printing press. We remain committed to this format, as it is a standard that we know well, and that will certainly be usable a century from now. Geological mapping is, however, undergoing rapid evolution due to

the availability of digital technology, accelerating computing capacity, and increasing levels of data input. During the 1990s, digital cartography was adopted, and we learned how to make a paper map with a computer. For at least two decades, the format of geological map products has been evolving beyond the constraints of the printing press. Users of GIS and Web mapping systems are accustomed to maps being zoomable and queryable. MGS, like other surveys, therefore is developing new map products that in many ways will serve as the foundation for a broad range of future outputs such as maps, databases, and 3D visualizations on the Web. Although questions about the format and distribution of these products remain to be clarified, the trend is clear.

New multi-layered state geological map

Having completed a considerable amount of new geological mapping since the last statewide bedrock geological map was published in 2000, and having reprocessed the aeromagnetic data, a new 1:500,000 State Bedrock Geological Map is now being produced. In GIS format, the map will have separate layers for water, Quaternary, Mesozoic, Paleozoic, and late Precambrian rocks (Figures 13 to 16). These layers will be removable, allowing the user to see the geology that lies beneath. Archean and other basement rocks will comprise the basal layer of the rock GIS themes. Additional themes will include diabase dikes and metamorphic grade, bedrock topography, outcrops, and sediment thickness. In addition, early planning is underway for effort toward a new state surficial geological map, to succeed the existing map produced in 1982.

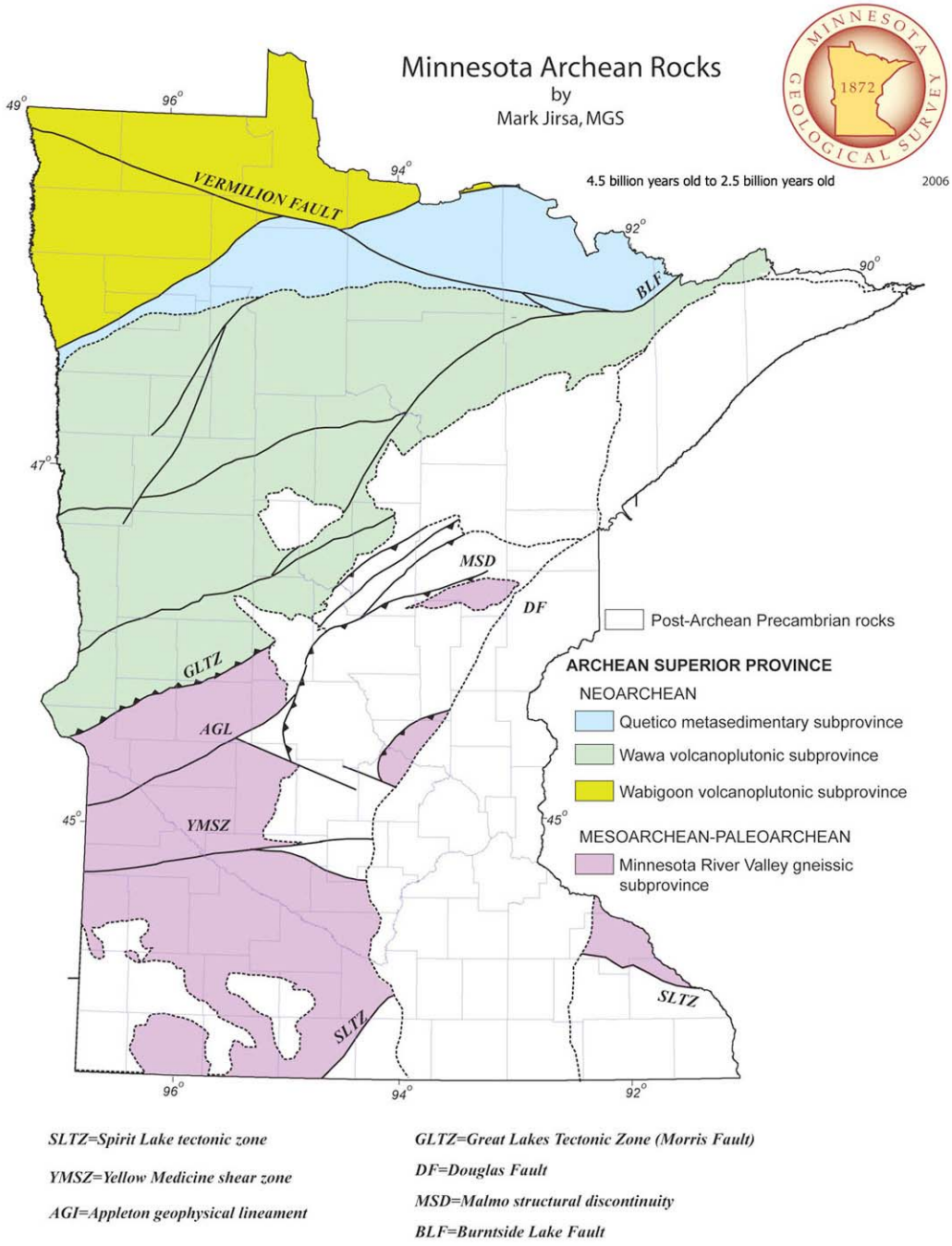

Figure 13. The basement layer of the new, GIS-based state bedrock map will largely consist of Archean rocks.

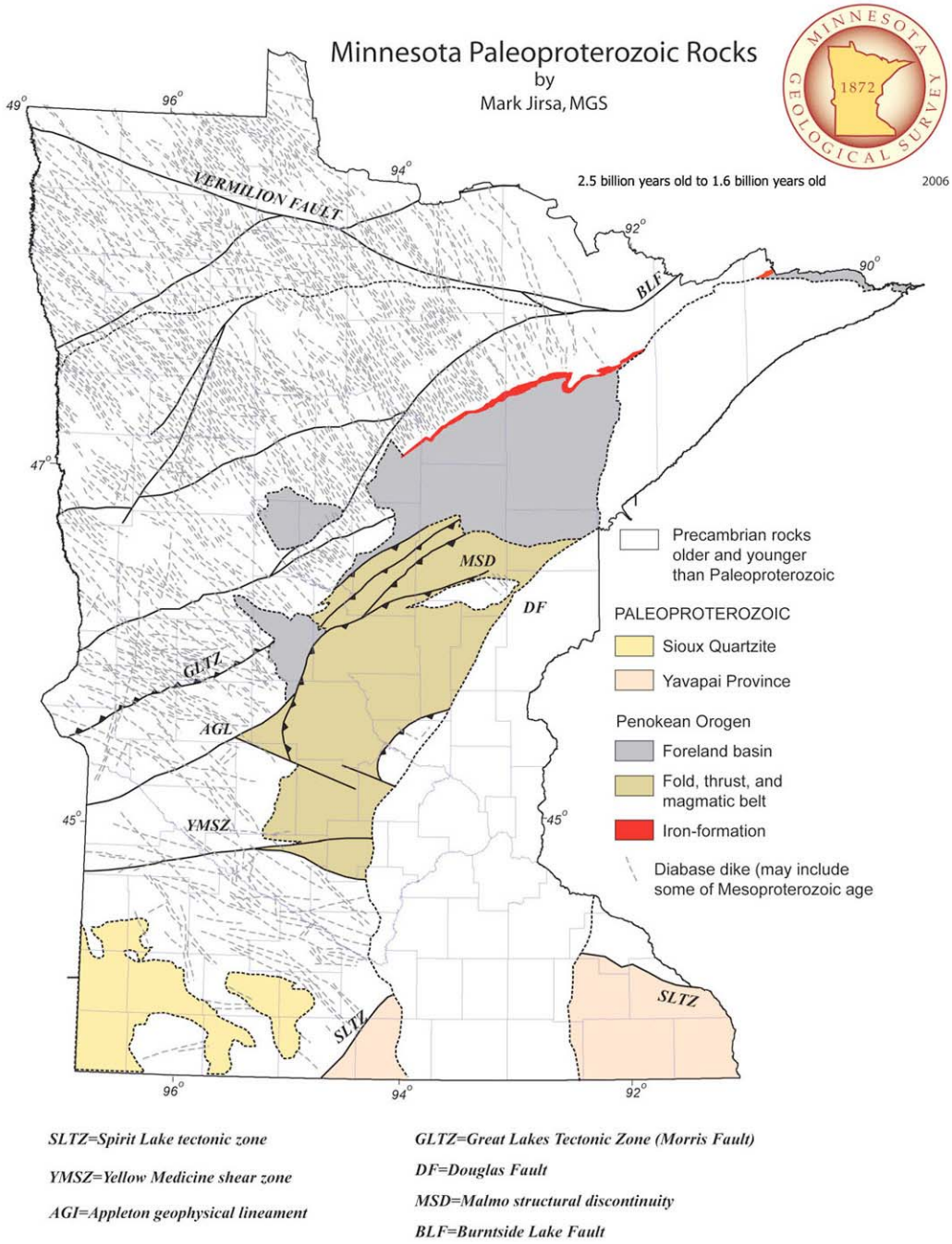

Figure 14. The Paleoproterozoic layer of rocks in the new state bedrock map.

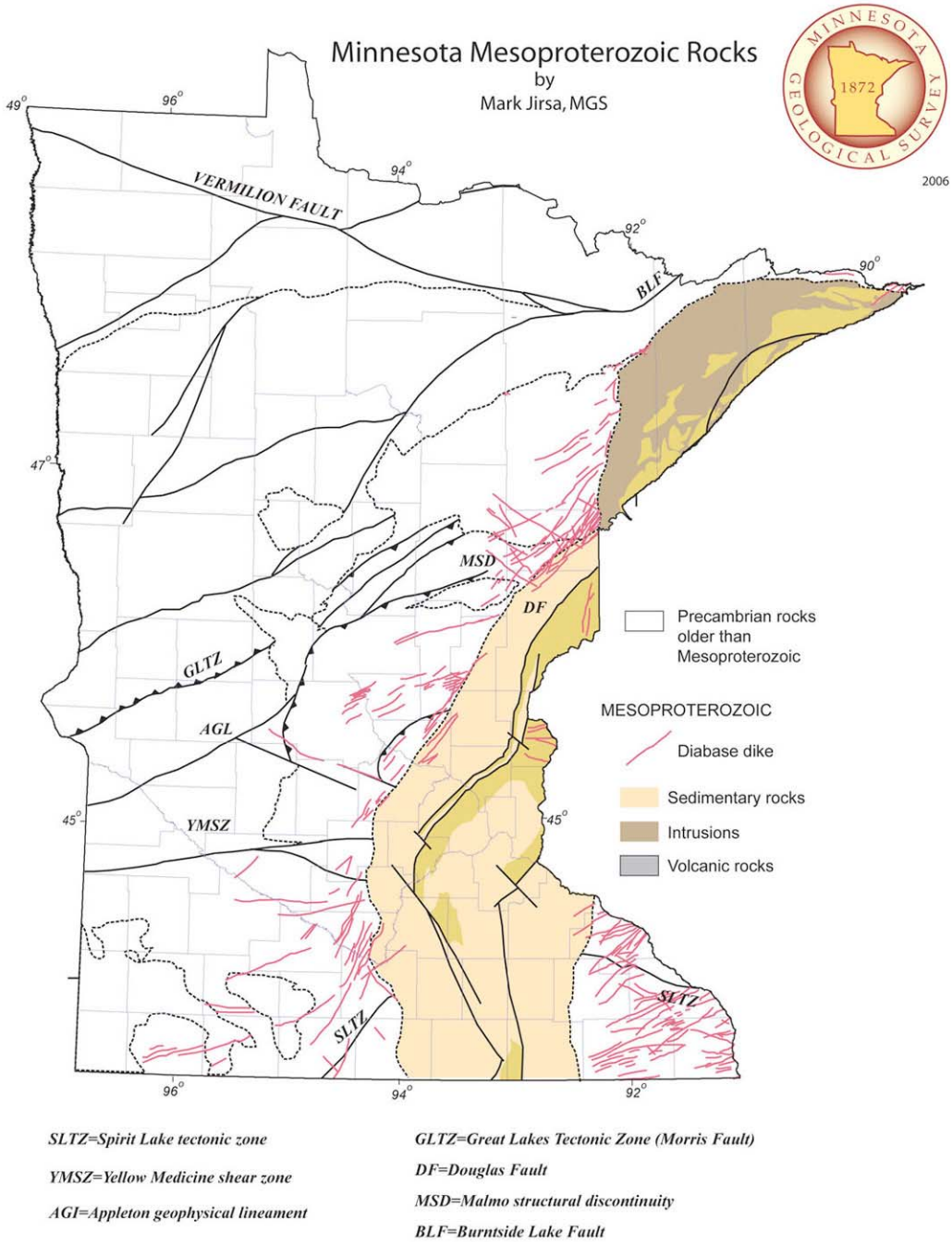

Figure 15. The Mesoproterozoic rocks in the new state bedrock map.

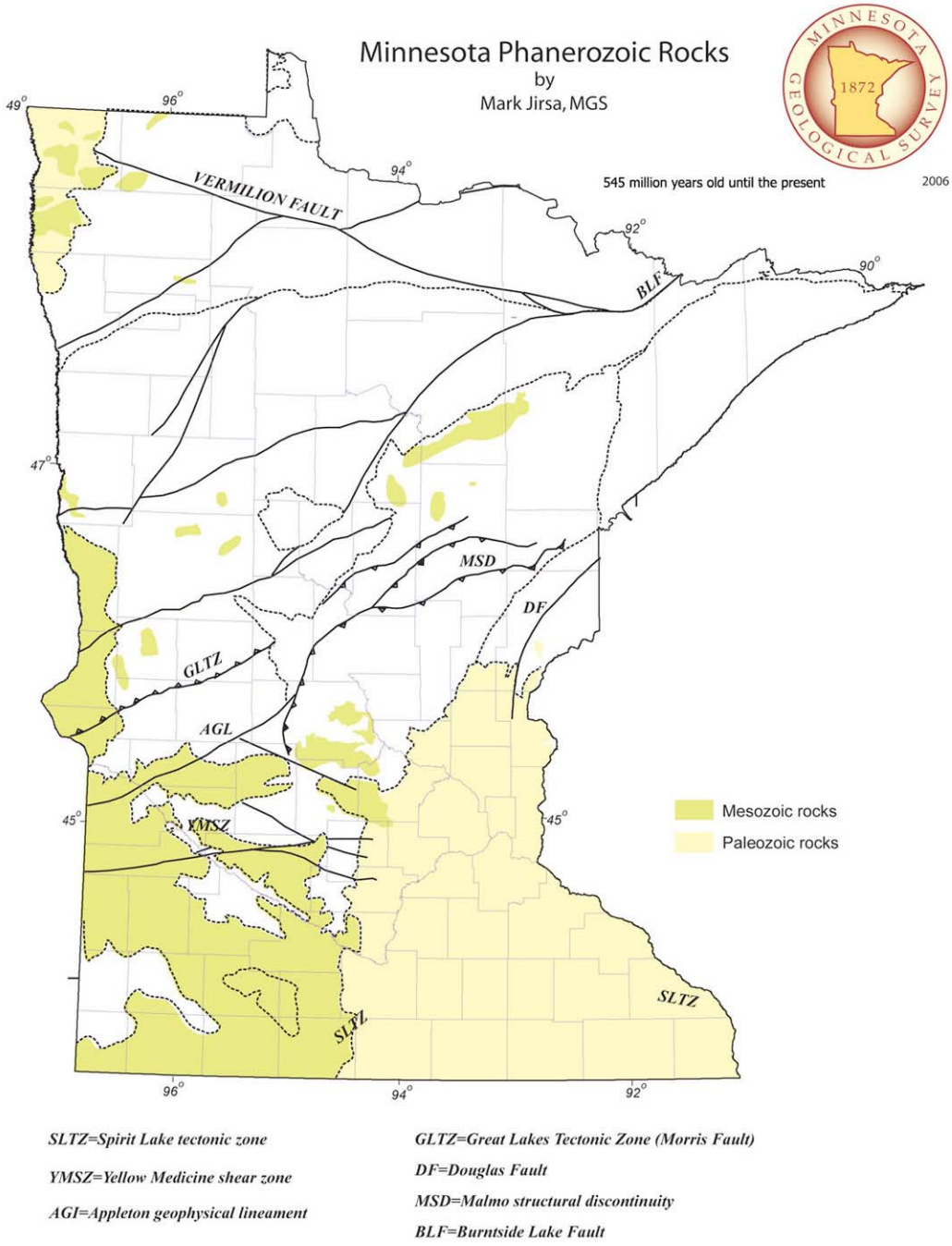

Figure 16. The Paleozoic and Mesozoic rocks in the new state bedrock map.

Web-optimized detailed geological mapping layers

While statewide maps of surficial and bedrock geology have been made available and are being updated to clarify context, it is mapping at 1:100,000 and 1:24,000 scale that is used for management applications at the county and local scale. Paper maps are still required, although many users rely on GIS resources and the Web to obtain information that they need on a day to day basis for their jobs. Standard geological maps with intricate legends, on paper or obtained

by time-consuming download, are not optimal for users who prefer to quickly obtain information and make decisions from a Web interface; with that said these maps will remain the authored, peer-reviewed foundation of our system. New detailed geological mapping layers, optimized for efficient Web query and accessibility are the new goal, with the added benefit that these layers can also act as the future gateway to more thorough documentation of standard maps and reports.

Statewide raster mosaics of existing detailed 1:100,000 and 1:24,000 scale surficial and bedrock geological maps thus will soon be prepared as a Web services initiative, initially to be a part of the international OneGeology project, but with plans for gradual vector digitization, harmonization, and enhancement of the mapping (Figure 17). Any statewide compilation of detailed mapping will, however, be incomplete for many years, and when complete, remapping will call for the pace of mapping to be maintained or increased. Focus therefore will remain on the maintenance and enhancement of sound field mapping skills, the steady progress of new field work, and production of new geological maps that will take us closer to eventual completion and enhancement of statewide detailed geological mapping coverage at a 1:100,000 scale or more detailed.

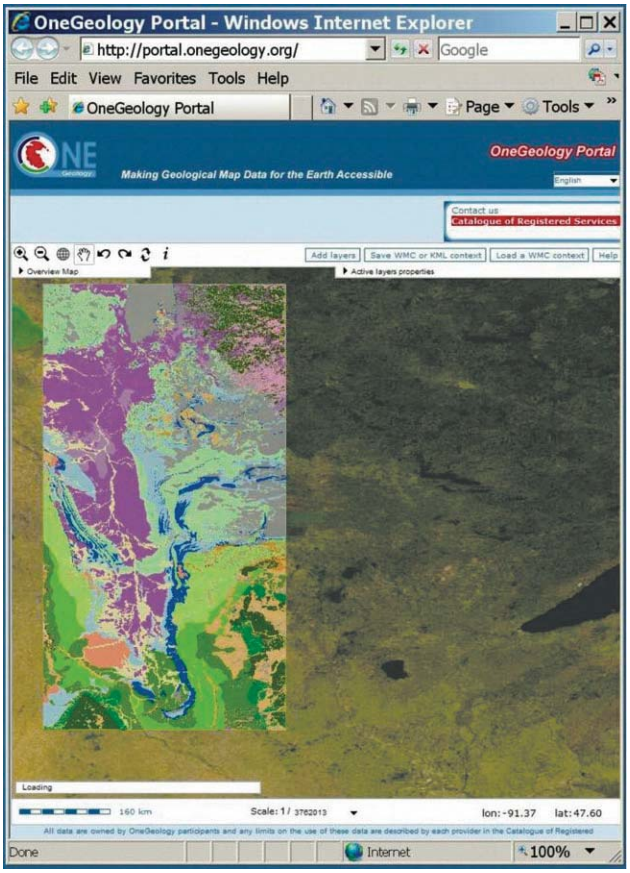

Figure 17. Compilation of detailed mapping has begun in cooperation with Manitoba Geological Survey; here, Red River Valley surficial geology is being viewed, and the screen extends east to Lake Superior.

County geologic atlases

MGS is steadily increasing its focus on the County Geologic Atlas program (Figure 18), managed in partnership with the DNR. These sets of 1:100,000 maps include bedrock geology, surficial geology, bedrock topography, depth-to-bedrock, and subsurface geology. The atlases have become progressively more digital and three-dimensional. The atlas products that MGS produces cost from $300,000 to $400,000 per county depending on the size, geological complexity, and database size. The DNR spends a roughly equivalent sum on its products largely related to ground-water resources. The county shares in the cost of each atlas. Currently twenty counties have a completed atlas and one of the early atlases from the 1980s has been updated as a result of financial support from that county; six other counties have atlases underway and five more are in the planning stage. The Minnesota Legislature has committed itself to enhanced groundwater protection, and the County Geologic Atlas program is seen as essential to achieving that objective.

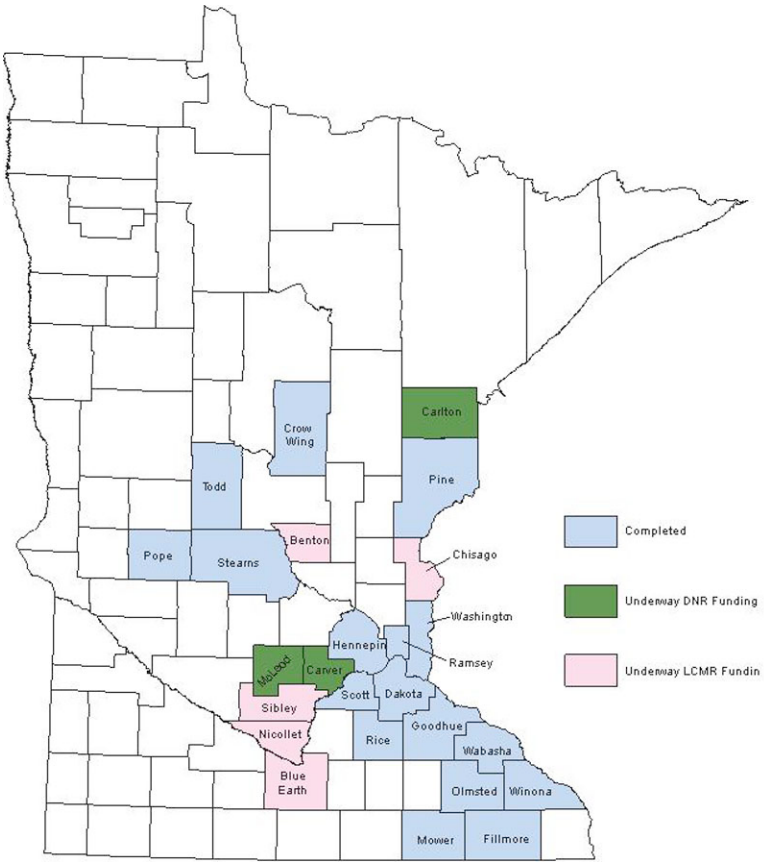

Figure 18. The principal Minnesota Geological Survey program is production of multi-layered 1:100,000 County Geologic Atlases, complete for about a third of the state.

County atlas plates are still offset printed, and MGS and its partners are committed to this high quality production of paper maps and their digital counterparts. These plates can include the database map, bedrock geology map, surficial geology map, subsurface geology depicted as cross sections and structure contours and isopachs, bedrock topography, depth to bedrock, and modeling of sand bodies as sources of drinking water.

Increasingly, however, the most important County Geologic Atlas product is the package of GIS resources that is distributed by DVD or ftp. These resources allow GIS managers to work with and query the entire database, including data for individual water wells. MGS has not yet developed protocols for version numbering and long-term maintenance of these GIS resources, nor are these materials optimized for Web accessibility. In the long-term, effort will also be directed at linking the atlases together. These opportunities and challenges will draw increasing attention in the months and years ahead.

INFORMATION DELIVERY

While publication sales, the Website, and ftp are being maintained, current intentions are to shift information products to Open Geospatial Consortium-compliant Web Services. This will allow users either to gain access to MGS products though the conventional MGS Website, or to gain direct access to the data through their preferred GIS platform or Web interface.

ACKNOWLEDGEMENTS

In addition to the ongoing dedication of Minnesota Geological Survey staff, support from the Minnesota State Legislature, the University of Minnesota, the Legislative-Citizen Commission on Minnesota Resources (LCCMR), the Minnesota Minerals Coordinating Committee, the Statemap component of the National Cooperative Geological Mapping Program, the USGS Data Preservation program, and partners throughout the State that makes this work possible is acknowledged and deeply appreciated.

REFERENCE

Runkel, A.C., Tipping, R.G., Alexander, E.C., Jr., Green, J.A., Mossler, J.H., and Alexander, S.C., 2003, Hydrogeology of the Paleozoic bedrock in southeastern Minnesota: Minnesota Geological Survey Report of Investigations 61, 105 p., 2 pls.